Codes and Standards Enhancement Initiative
For PY2004: Title 20 Standards Development

Analysis of Standards Options
For
Unit Heaters and Duct Furnaces

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1 Introduction

The Pacific Gas and Electric Company (PG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standards and options for unit heaters and duct furnaces.

2 Product Description

Reznor invented the unit heater in 1936 and the technology has not changed significantly since then. The unit heater is an unducted space heater, typically installed in ceiling mounted locations. Fuel sources included natural gas, oil, LPG, and electricity with approximately 80% of the units burning natural gas. It is a simple device used primarily to heat industrial and commercial buildings. Low head applications use propeller fans to deliver heat to open areas. The primary advantage of unit heaters is their simplicity and low first cost making them ideal for heating-only applications with moderate comfort requirements (high bay applications, warehouses, factories, etc.).

Figure 1: Typical Unit Heater (source: Modine)

Unit heaters are available in sizes ranging from 25,000 Btu per hour (Btuh) fuel input to 6,250,000 Btuh (CEC, 2002). These devices have typical steady state thermal efficiencies of 80 to 84 percent with just three condensing models available at 92 and 93 percent. The national market is dominated by three manufacturers (Modine, Reznor, and Sterling) who produce approximately 90% of the equipment (ACEEE, 2003). All natural gas and all but eight liquid petroleum gas (LPG) fired models listed for the California market have an intermittent ignition device (IID) (CEC, 2002.).

Duct furnaces are similar but the fan or blower is provided separately. Duct furnaces are available in sizes ranging from 56,000 to 1,200,000 Btuh fuel input. Outdoor versions are supplied by four main manufacturers: Modine, Sterling, Reznor, and Hastings. Indoor units are available from these manufacturers and also from Airfan Engineered Products. All California listed devices have an IID (CEC, 2002).

Larger capacity devices called industrial air heaters are available from one manufacturer, Cambridge Engineering Inc. (CEI), from 395,000 to 5,556,000 Btuh input. This group has a thermal efficiency of 92%. All California listed devices have an IID (CEC, 2002). These are direct-fired devices that exhaust combustion gases to the heated zone. Combustion air is drawn from outside. CEI has trademarked this method as “100% fresh air” (CEI, 2002). Industrial air heaters are not within the scope of this analysis.

The standing pilot light has been eliminated from the California market by Title 20 appliance standards (CA, 2002). Replacement of the standing pilot with an IID may also include an automatic flue damper. This measure is accompanied with a power vent in some models which significantly reduces off-cycle losses. Off-cycle losses through the vent flue represent the primary parasitic loss for gravity vented units, reducing their seasonal efficiencies from 80-83% to 62-64% (ACEEE, 2002). The high off-cycle losses for gravity-vented units is primarily due to stratification affects and the thermal losses associated with having an open exhaust flue located at the warmest part of the building.

Typical unit heater fan efficiencies are in the range of 200-250 Watts/1000 cfm (ACEEE, 2002), which is considerably more efficient than typical ducted systems due to low external static pressure. For mid-sized units, electricity consumption amounts to only about 1.5% of annual site energy consumed.

3 Market Status

3.1 Market Penetration

According to a Gas Research Institute report, natural gas-fired unit heaters supply 38% of the commercial gas-heating load nationwide (Manix et al, 1997). There are regional differences in unit heater penetration with the 1999 Commercial Buildings Energy Consumption Survey (CBECS, 1999) reporting 18% of commercial floor space in the Pacific region heated by unit heaters. With lack of any better data, this represents a good approximation of the California market. DOE estimates there are 3.2 million unit heaters and 239 thousand duct furnaces in the U.S. (DOE 2002). Economic census data indicate that 12% of establishments that typically use unit heaters (manufacturing, transportation, and warehouse) are located in California (USCB 1997). We therefore estimate that there are 182,000 unit heaters in California[1].

3.2 Sales Volume

Annual U.S. sales were 216,000 in 2000 and 166,000 in 2001 (GAMA, 2001). California specific market share data is not available. Using the same assumptions as in section 3.1,

[1] 3.2 million x 12% x 18%/38%

we estimate California annual unit heater sales at approximately 12,200 units in 2000 and 9,400 in 2001.[2]

3.3 Market Penetration of High Efficiency Options

The simplest unit heater has a standing pilot light and gravity damper. California Title 20 limits standby losses (CA, 2002) which has effectively eliminated pilot lights on natural gas-fired devices, although not on some LPG-fired devices (CEC, 2002).

Several efficiency measures exist which can increase the operating efficiency of unit heaters and duct furnaces. These include automatic flue dampers, intermittent ignition devices (IID), power vent combustion blowers, separated combustion, pulse combustion, and condensing combustion.

Automatic flue dampers, or vent dampers, have been applied to some gravity-vented units. An automatic flue damper is an electric motor operating a stack valve to limit off-cycle losses. To date, these have not been widely accepted.

Use of a “power vent” combustion air blower can eliminate the standing pilot on natural gas-fired units. The exhaust stack is blocked during off-cycles, reducing standby losses to almost zero. (Propane units have a higher standby limit and may employ a pilot and gravity vent.) In 1989, these units accounted for about 20% of the market; however recent market data from the three major manufacturers indicate current national market share is roughly 45% (ACEEE, 2002).

The next step up in efficiency involves drawing combustion air from the outside rather than the heated zone, called “separated combustion” whereby combustion air is preheated by the exhaust gas to recover additional heat. This feature is called an economizer in commercial boiler design. Market share for separated combustion technology is estimated at 4% (Manix et al, 1997).

Pulse combustion is a process that results in more complete combustion of the fuel. The final step up in efficiency involves a condensing furnace to recover latent heat in the exhaust.

4 Savings Potential

4.1 Baseline Energy Use

Little data are available documenting unit heater energy use. Typical applications in warehouses and high bay “semi-conditioned” facilities (often with open doors) make accurate annual energy projections problematic. Table 1 lists the technologies and efficiencies of various types of unit heaters. Efficiencies are listed both as steady-state thermal efficiency and as a seasonal efficiency, accounting for electrical use and off-cycle losses.

[2] Duct furnace sales were 13,000 and 11,000 for 2000 and 2001 respectively (GAMA-2001).

Table 1. Typical Steady State and Seasonal Efficiencies

Technology	*Thermal efficiency*	*Seasonal efficiency*
Pilot, gravity vent	78% - 82% (1)	63% (1)
IID, gravity vent	78% - 82% (1)	66% (3)
IID, power vent	80% - 83% (1)	80% (1)
Separated combustion	80% - 83% (1)	80% (1)
Pulse combustion	90% (2)	82% (2)
Condensing	>90% (1)	90% (1)

(1) ACEEE, 2003; (2) DOE, 2002; (3) DEG estimate.

Table 2 presents an annual energy use and operating cost calculation for a "base case" gravity vent unit heater derived from an ACEEE study (ACEEE, 2003). The method assumes unit heaters are typically oversized by 100%. One thousand annual full-load operating hours are conservatively estimated for typical California applications, or approximately half of the national average hours estimated by ACEEE. It is important to note that the current California standards effectively require an IID.

Table 2: Typical California Gravity Vent Unit Heater Energy Use Estimate

Median unit heater input capacity	220,000	Btu/h
Typical oversizing	100%	
Diversified peak load	110,000	Btu/h
Estimated CA heating load hours	1,000	hours
Heat delivered to space	693	therms
Gravity Vent Characteristics		
Annual use	1056	therm/yr
Typical cost	$0.80	$/therm
Estimated annual efficiency, gravity unit	66%	
Annual gas cost	$ 845	

4.2 Proposed Test Method

The California regulations have for many years required measuring and reporting the energy efficiency of unit heaters and duct furnaces for compliance with minimum standards using the ANSI Z83.8-1996 test method. The new provisions in this report would not change this situation, nor require any additional testing.

4.3 Efficiency Measures

Potential efficiency measures to increase the seasonal performance of unit heaters include power vent, automatic flue damper, pulse combustion, and condensing heaters. A power vent or automatic flue damper represents the most logical next step in improving unit heater operating efficiency.

4.4 Standards Options

Given the increasing penetration of power vent units, it would be prudent to require power vent technology or automatic flue dampers as a minimum efficiency level. Off-cycles losses of open flue systems can be very high and can be cost-effectively addressed.

4.5 Energy Savings

Table 3 summarizes estimated savings relative to the "base case" gravity vent unit heater (with IID) presented in Table 2. This represents current requirements in California for natural gas unit heaters. The power vent technology significantly improves seasonal efficiency by largely eliminating off-cycle convective losses through the flue. Estimated savings for the power vent technology are approximately five times the savings of the IID. More advanced combustion technologies, such as pulse combustion and condensing, further boost seasonal efficiencies and projected annual savings.

Table 3: Annual Savings Estimates for Various Unit Heater Options

Option	*Estimated Efficiency*	*Gas Use (therms)*	*Gas Savings (therms)*	*Cost Savings*
Power Vent	80%	866	190	$152
Pulse Combustion	82%	845	211	$169
Condensing	90%	770	286	$229

5 Economic Analysis

5.1 Incremental Cost

Power vent technologies are moderately more expensive than gravity vent unit heaters. Manix (Manix et. al. 1997) interviewed market participants to determine installed costs of both gravity vent and power vent unit heaters. Costs (in 1997 dollars) range from $10-$11 per kBtuh input for gravity vent systems to roughly $13 per kBtuh for power vent systems, to $25 per kBtuh for pulse and condensing units. DOE estimates the cost of a 225 kBtuh condensing unit at $4,925 (DOE, 2002). Table 4 summarizes incremental costs relative to a "typical" 220 kBtuh gravity vent unit. A more recent cost estimate (ACEEE, 2003) suggests a $300 incremental cost for power vent technology.

Table 4: Incremental Costs (220 kBtuh unit)

Technology	*Base Cost*	*Incremental Cost*
Base	$2,310	-
Power Vent	$2,860	$550
Pulse Combustion	$5,000	$2,690
Condensing	$5,000	$2,690

5.2 Design Life

The average life of a gas-fired unit heater is approximately 20 years (ACEEE, 2003). The average life of a duct furnace ranges from 15 to 20 years according to DOE (DOE, 2002). For purposes of this analysis we have conservatively assumed a design life of 15 years.

5.3 Life Cycle Cost

Based on the 15-year design life, a "per therm" savings value of $7.035/therm is applied to energy savings. Table 5 summarizes the customer benefit of both power vent and condensing options. Present value of annual energy savings is calculated per California Energy Commission 2000 Appliance Standards - Life Cycle Cost Analysis document Table 1A.

Table 5: Analysis of Customer Net Benefit

Option	*Design Life (years)*	*Annual Energy Savings (therms)*	*Present Value of Energy Savings**	*Incremental Cost*	*Net Customer Present Value***
Power Vent	15	190	$1,337	$550	$787
Condensing	15	286	$2,012	$2,690	($678)

*Present value of energy savings calculated using a Life Cycle Cost of $7.035/therm (CEC 2001).
**Positive value indicates a reduced total cost of ownership over the life of the appliance

6 Acceptance Issues

6.1 Infrastructure Issues

Since the marketplace is naturally transitioning towards power vent systems, there are no apparent obstacles in the path of requiring a power vent system (or automatic flue dampers) as part of a standard.

6.2 Existing Standards

Although the U.S. Department of Energy lists unit heaters as a product class for which standards could be developed, it presently does not have the legal authority to do so. U.S. Senate legislation requiring a rulemaking for unit heaters passed in May 2002, but the

2002 Energy Bill died in Conference Committee. The following language is contained in the House-Senate conference report which has been ratified by the House:

> ***SEC. 133. ENERGY CONSERVATION STANDARDS FOR ADDITIONAL PRODUCTS.***
> *(c) NEW STANDARDS.—Section 325 of the Energy Policy and Conservation Act (42 U.S.C. 6295) is amended by adding at the end the following:*
> …
> *(aa) UNIT HEATERS.—Unit heaters manufactured on or after the date that is three years after the date of enactment of this subsection shall be equipped with an intermittent ignition device and shall have either power venting or an automatic flue damper.*

If this version is passed into law then the existing Title 20 standards for unit heaters will remain in effect for the three years after the date of enactment, but any new unit heater standards will be preempted.

7 Recommendations

Based on trends in the unit heater market, we propose that a prescriptive requirement be developed which addresses off-cycle stack losses. Current Title-20 requirements have effectively eliminated the standing pilot from natural gas fired unit heaters. The following language should be added to eliminate off-cycle exhaust stack losses.

7.1 Proposed Changes to Title 20 Code Language

The following standards language is recommended for section 1605.3 (e)

(e) ***Gas and Oil Space Heaters.***

(1) ***Boilers, Central Furnaces, Duct Furnaces, and Unit Heaters.***

(A) The efficiency of boilers, central furnaces, duct furnaces, and unit heaters shall be not less than, and the standby loss shall be not greater than, the applicable values shown in Tables E-5, E-6, and E-7.

(B) All natural gas fired unit heaters and duct furnaces shall have either power vent or an automatic flue damper.

8 References

ACEEE, 2002: Sachs, Harvey M., Toru Kubo, Sandy Smith, Kalon Scott, *Residential HVAC Fans and Motors are Bigger Than Refrigerators*, ACEEE, 2002.

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CA, 2002: California Code of Regulations, Title 20: Division 2, Chapter 4, Article 4, Sections 1601-1608: *Appliance Efficiency Regulations*, effective November 27, 2002.

CEC, 2002: http://www.energy.ca.gov/appliances/appliance/excel_based_files /space_heaters/, 2002

CEI, 2002: Cambridge Engineering, Inc., http://www.cambridge-eng.com/ products/s_series.asp

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GAMA, 2001: Gas Appliance Manufacturers Association, Statistical highlights, 10-Year Summary 1992-2001: http://www.gamanet.org/member/statistics/TYS1992-2001.pdf

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Manix, A., M. McElhattan, and P. McGreevy, 1997. Topical Report: Commercial Space Heating Equipment Market. GRI 97/0100.

USCB, 1997. Economic Census 1997. http://www.census.gov/epcd/www/econ97.html. United States Census Bureau. 1997.